Portable Heart Rate Measurement for Remote Health Monitoring System

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***Abstract*— This paper presents a design of portable heart rate monitoring system which is part of a project called Home-smart Clinic. Home-smart Clinic is developed in order to connect medical personnel and patients remotely. Remote health monitoring system is beneficial to the patients and society where the implementation of such system will save hospital bill, waiting time and reduce traffics in the hospital. The prime objective of this paper is to design and develop heart rate measurement device for which real time data could be observed by the doctor via internet. History data could also be acquired; therefore the doctor can interpret the trend of the data to identify the conditions of the patients. In the proposed health monitoring system, heart rate and body temperature wireless sensors were developed, however this paper only focus on heart rate monitoring system. The main components involved in this project are pulse sensor, microcontroller (Arduino with Ethernet shield), and wireless communication device (Xbee). The portable heart rate measurement device was tested to a group of voluntary students. Results showed that the real-time heart rate reading successfully monitored locally (at home) and remotely (at doctor's computer).**

Keywords—health monitoring; heart rate sensor; Arduino; medical device

I. INTRODUCTION

Nowadays, with the increase in elderly and chronically ills population in human society, continuous health monitoring is needed and become progressively more important. However, staying in the hospital for months or even years will lose their quality life and costly. The routine activities in the ward are measuring the vital signs for example heart rate, blood pressure and body temperature. These activities can actually be done remotely if remote health monitoring system is implemented.

The application of remote health monitoring system is practically new in Malaysia and many other countries. As reported by The Star dated 15 June 2013, National Heart Institute (IJN) has launched remote monitoring system via Merlin.net, developed by St. Jude Medical Inc, USA and becomes the first hospital in Malaysia to connect doctors and patients through the web. The application of such system is to reduce follow-up visit and traffic congestion in the hospital which are the common situation in other private and government hospitals.

The remote health monitoring becomes possible with the availability of wireless sensors and wireless sensor network. Body temperature and heart rate measurement devices are the examples of wireless sensors used in medical devices. Dobrescu et. al., (2008) mentioned that the growth of internet services and wireless sensor network has open up opportunities in healthcare [1]. Wireless sensor network has many benefits where data collection and monitoring service are feasible [2]. In home health monitoring, the technology allows patients to monitor their own vital signs from their home and communicate results to a hospital professional wirelessly. In fact, the doctor could increase the ability to address a problem before a patient requires acute care [3].

Heart rate is the number of heartbeats per unit of time, usually measured at the wrist. Heart rate shows the health condition of a person and can give early indication of heart diseases. There are several existing heart rate measurement devices available on market such as Sensium Life Pebble by Toumaz Technology [4]. This portable device is wireless and able to transmit the information to base station via radio frequency. The data collected will then be transmitted to a USB device that is plugged into a computer. Nevertheless the signal range is very limited (5 meter). Pagewriter TC50 by Philips is a very advanced device that could help doctor to monitor not only heart rate but also ECG results of patients [5]. Due to its huge size, the device is not portable. Digitrak XT Holter Recorder also by Philips has smaller size and portable, allow patients to wear this device for a few days before handed in to the hospital for result analysis [6]. Although these heart rate devices have the ability to store data to be analysed and connected wirelessly to the base station, there is no web based system that allows the doctor (at the

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hospital) to obtain real-time data from the patients (at home) as has been proposed in this project.

One of the fundamental systems in medicine is the monitoring system that can help the medical checkup do the diagnosis for the data collection [7]. Xbee modules have been used to take the body temperature of the patients. Using Zigbee wireless network configuration, two nodes (coordinator and router) are needed. Temperature sensor node is attached to the coordinator while a router is attached to a computer containing monitoring program. Xbee 50mW wire antenna has been used to allow mesh network where six inputs are monitored at one time. Besides body temperature, patients status, saline level, nurse check in, food serving, drug serving and patient motion are monitored. Alarm function for continuous treatment and abnormal conditions is also available.

Similar methodology has been used by Yusoff. et. al, (2010) except peripheral interface controller (PIC) has been used to process the information from the temperature sensor [8].

Reddy & Damodhar (2012) used multi sensors to determine temperature, heart rate and blood pressure from human body and ZigBee has been used as a wirelees network in order to send signals to the PC via the RS-232 serial port communication interface [9]. Instead of displaying the readings on the computer's screen, the computer sends GSM short message to the mobile phone.

The wireless monitoring system proposed in above-mentioned literature are only working for personal area network (PAN). In the proposed remote health monitoring system, both PAN and Wireless Local Area Network (WLAN) are available. The doctor's can monitor patients' status anywhere as long as there is internet fascility.

II. METHODOLOGY

A. *Remote Health Monitoring System Architecture*

The overall block diagram of remote health monitoring system is shown in Fig. 1. The system is divided into three parts, which are data acquirement unit (patient monitoring), data processing unit (database system) and data communication unit (diagnostic analysis). Data acquiring unit consists of any measuring devices where in this particular project, heart rate and temperature sensors. This system provides interaction between each part in a real time monitoring, processing and reporting. From the diagnostic analysis, the doctor can get the information of the conditions of their patient(s) just by accessing into the remote database which only requires an internet connection. The measuring devices will be connected to the Arduino and Ethernet shield. Ethernet shield plays an important role in order to send the data in a real time monitoring.

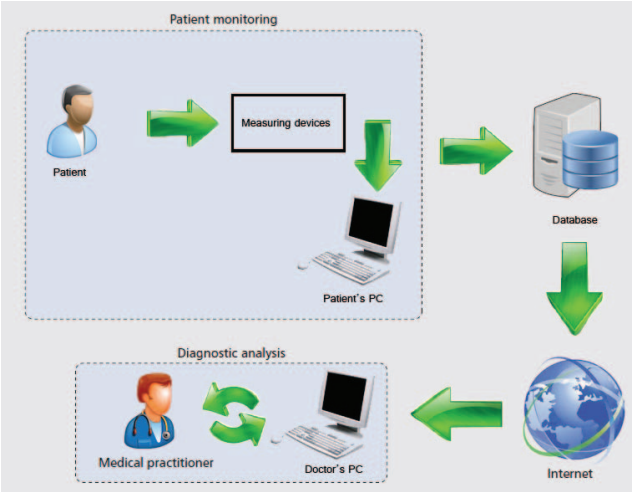

Fig. 1 Block diagram of remote health monitoring system

B. *Heart rate Measurement Device*

In this project, wireless heart rate and temperature sensors have been designed. However, this paper will only focus on pulse sensor that measures heart rate.

Pulse sensor used in this project utilised photoplethysmograph technique to detect pulse. photoplethysmograph detects pulses signal by exploiting light as the pulse detector. It detects changes in blood volume in tissue that is synchronous with heart beat. As it is simple and low-cost, it is often used non-invasively to make measurement at the skin surface [Huang et. al. ref 6i]. Pulse Sensor Amped, a plug-and-play heart rate sensor for Arduino manufactured by PulseSensor.com has been chosen in this project. The pulse sensor amplifies the raw signal, and normalizes the pulse wave around V/2 (midpoint in voltage). Pulse Sensor Amped responds to relative changes in light intensity. If the amount of light incident on the sensor remains constant, the signal value will remain. If more light detected, the signal will goes up and when less light detected, the signal goes down. In other words, the pulse sensor measures subtle changes in light from expansion of the capillary blood vessels to sense the heartbeat. Fig. 2 shows the Pulse Sensor Amped, a pulse sensor used in this project. The size, price and accuracy of this pulse sensor make it suitable to be used all day.

Before the physical connections were made, the hardware configuration of Home Smart Clinic was simulated as shown in Fig. 3. Nine volt battery has been used as the supply voltage and LCD display displays the patient's heart for self-monitoring. There is a buzzer which functions as alarm indicator for abnormal readings. It will keep on beeping until the normal reading is obtained or emergency button is pressed.

Fig. 2 Pulse sensor

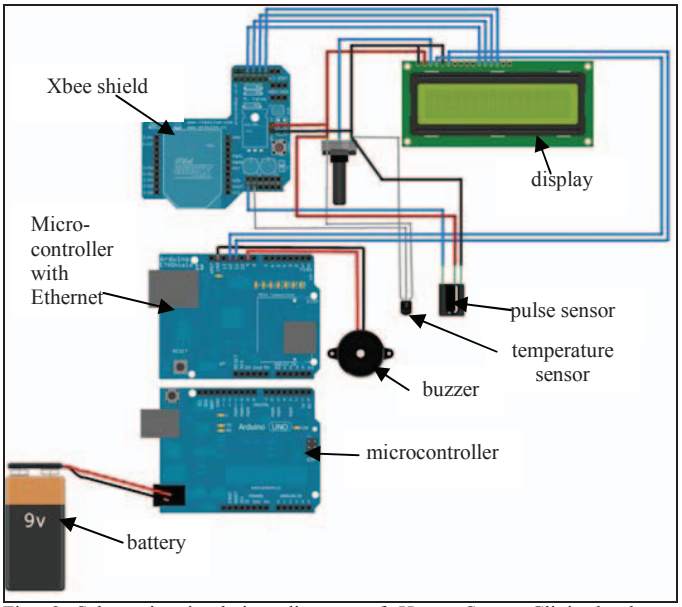

Fig. 3 Schematic simulation diagram of Home Smart Clinic hardware configuration.

C. Data Acquirement Unit

Arduino Uno which works based on ATmega 328 embedded together with Ethernet shield has been used as the brain of the Home Smart Clinic system. Arduino has been used to connect the heat rate measuring device to real time monitoring database via internet access. There are 14 digital input/output pins, 6 analog inputs, and a USB port. USB port is important for interfacing and as a medium to upload programmed code to the hardware. Xbee shield was connected on the top of Ethernet shield, as shown in Fig. 4.

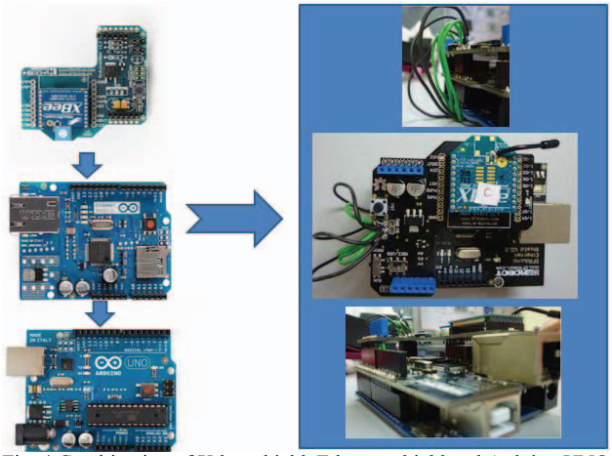

Fig. 4 Combination of X-bee shield, Ethernet shield and Arduino UNO

D. Data Communication Unit

MySQL, open source software has been used to design the database for patient's personal information and measurement of vital signs. Fig. 5 shows graphical user interface (GUI) which provides the interface for both clinician and patients. This graphical user interface is also used for body temperature monitoring system as well. Only the Administrators or authorised clinicians are able to view and edit patient details, add new records and track health status (real time measurements of heart rate and body temperature and history data). Patients are able to access the website to view their own clinical records. Fig. 6 shows the login page for Home Smart Clinic web application. This web application can only be accessed by certain authorities that have been registered by the administrator in the database system. Fig. 7 shows the main page for the admin that has authority to view the patient's clinical record. Fig. 8 shows the interface of patient details.

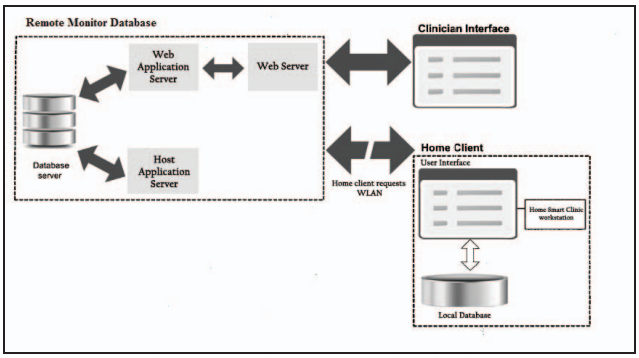

Fig. 5 Layout for remote monitor database

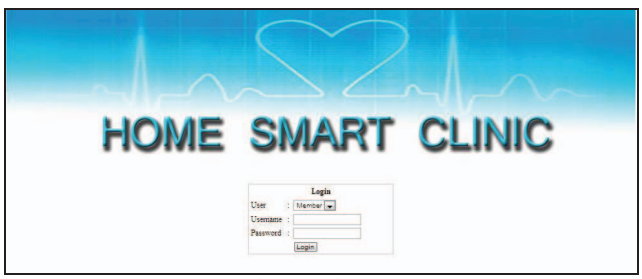

Fig. 6 Login page

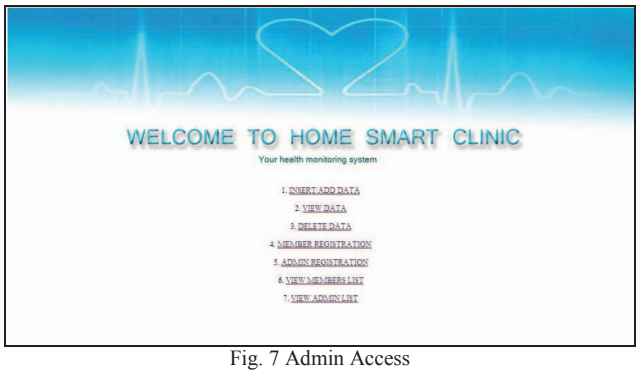

Fig. 7 Admin Access

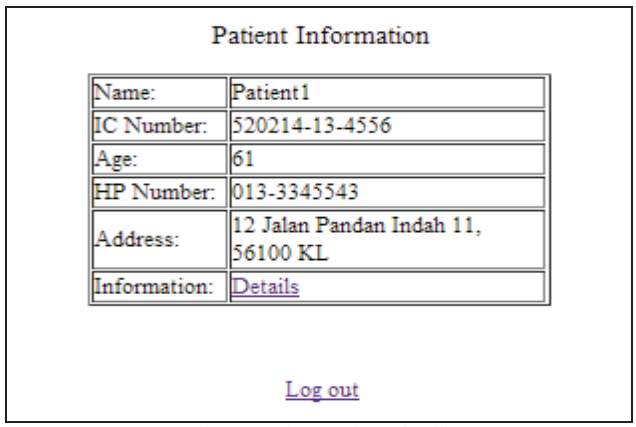

Fig. 8 Member (patient) details

III. RESULTS AND DISCUSSIONS

A. Experiment Setup

The pulse sensor with data acquirement unit and computer containing Home Smart Clinic web application were set up as shown in Fig. 9. LCD display is connected to the micro-controller (Fig. 10) in order to help the patient to visualized the local reading.

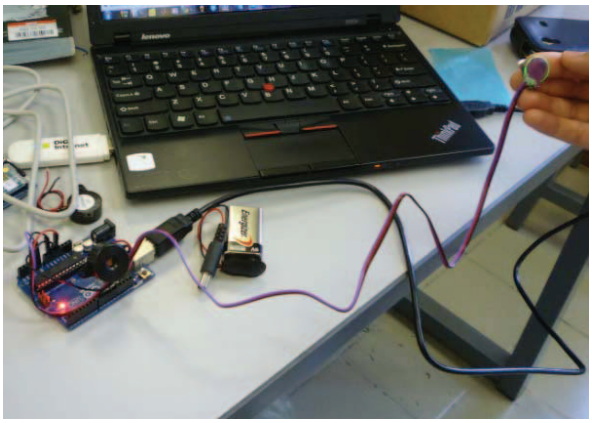

Fig. 9 Experiment setup

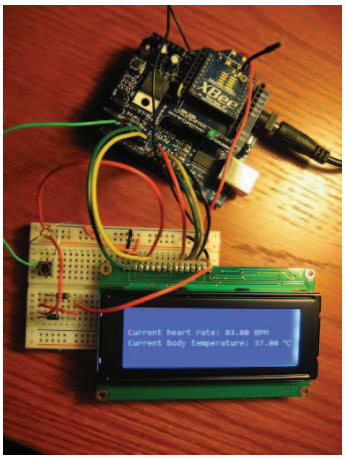

Fig. 10 Local display of heart rate measurement

Arduino IDE software was used to program the micro-controller (Arduino Uno) so that the signal from the pulse sensor can be represented in digital form. The pulse was measured in beats per minute.

Remote monitor database which involved wide area network (WAN) was used to display the results in a standard web browser technology in order to connect to the database and web application server. When the coding has been uploaded into Arduino, it will make a connection from Ethernet shield to get a response from PhpMyAdmin. With the web application, the clinician is able to access the patient's record as well as all measurements taken remotely.

The website of this project can be accessed at http://homesmartclinic.freetzi.com.

B. Result Validation

The pulse sensor device has been tested on an individual and the reading was observed from the LCD display. For validation, the result was compared to the traditional way of heart rate measurement (i.e. calculate the number of pulse for in one minute). Measurements were made at the wrist of the same patient. Based on several measurements when the patient was in relax condition, the readings is summarised in Table 1.

Table 1 Comparisons of the heart rate reading using the proposed heart rate measurement device and manual calculation

No	Pulse sensor	Manual calculation
1	83	84
2	87	87
3	83	83
4	85	84

Test result shows that the pulse sensor readings are very close to manual calculation.

During the test conducted, data was acquired from pulse sensor and temperature measurement device through serial communication of Arduino. Fig. 11 shows the real time reading of both pulse sensor and temperature measurement device. The data can also be accessed remotely, through the Home Smart Clinic website, as shown in Fig. 12.

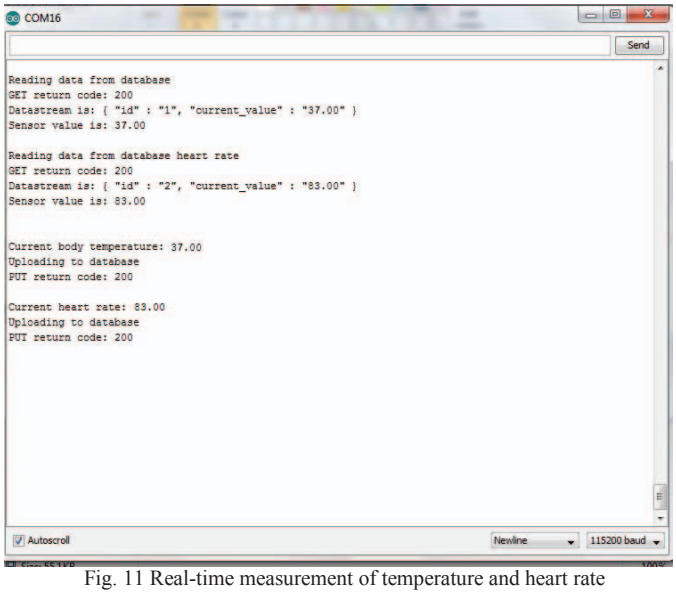

Fig. 11 Real-time measurement of temperature and heart rate

Fig. 12 Screenshot of the Home Clinic website

IV. CONCLUSIONS

The objective of this project to design and develop heart rate measurement device for remote health monitoring has been successfully achieved. The device is working very well and the performance is comparable to manual calculation method. The performance and efficiency of the device can be further improved in future especially in terms of sizing. Possibly, the heart rate sensor can be designed to be worn at the ear lobe so that it will not interrupt patient's activities.

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